Spacetime weave - Bit as the connection between Its or the informational content of spacetime

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In this essay I will discuss the relation between information and spacetime. First I demonstrate that because of diffeomorphism invariance a smooth spacetime contains only a discrete amount of information. Then I directly identify the spacetime as carrier of the Bit, and derive the matter (as It) from the spacetime to get a direct identification of Bit and It. But the picture is stationary up to now. Adding the dynamics is identical to introducing a time coordinate. Next I show that there are two ways to introduce time, the global time leading to quantum objects or the local time leading to a branched structure for the future (tree of the Casson handle). This model would have a tremendous impact on the measurement process. I discuss a model for the measurement of a quantum object with an explicit state reduction (collapse of the wave function) caused by gravitational interaction. Finally I discuss some applications of the model to explain inflation and the Higgs potential.

Dedicated to the memory of C.F. von Weizsäcker

I. ON BITS AND ITS

In 1990, Wheeler described its the Its concept "it from bit" by the words [1]: It from bit. Otherwise put, every 'it'—every particle, every field of force, even the space-time continuum itself—derives its function, its meaning, its very existence entirely—even if in some contexts indirectly—from the apparatus-elicited answers to yes-or-no questions, binary choices, bits. 'It from bit' symbolizes the idea that every item of the physical world has at bottom—a very deep bottom, in most instances—an immaterial source and explanation; that which we call reality arises in the last analysis from the posing of yes–no questions and the registering of equipment-evoked responses; in short, that all things physical are information-theoretic in origin and that this is a participatory universe. But Wheeler was not the first. A similar program was carried out by Carl Friedrich von Weizsäcker [2] and his students since the 1950's. Inspired by Heisenberg and Pauli's unified field theory (non-linear SU(2) spinor theory), Weizsäcker considered the simplest bit of quantum information, the ur-alternatives, vectors in the 2-dimensional complex Hilbert space $\mathbb{C}^2$. But the central point in Weizsäckers argumentation is the development of a time-like logic (directly leading to quantum logic) and the relation to probability theory. In particular, he tried to obtain the quantum mechanics by using the ur-alternatives. Here he used 4 approaches to derive the abstract quantum theory (Hilbert space, dynamics). For instance, one approach starts with ur-alternatives and construct a lattice of ur-alternatives leading directly to the Hilbert space. In particular the spacetime is a derived concept in his theory. At this point I disagree with the approach and will discuss a geometric model below. But now let us analyze the two main concepts: the Bit and the It.

So what is information (or the Bit)? Let us look into the standard textbook definition: Information refers to an inherent property concerning the amount of uncertainty for a physical system. First we consider a classical physical system. All information about this system is encoded into the physical state, specified by a distribution function in the multidimensional phase space for all its degrees of freedom. This distribution evolves according to Liouville's theorem, which conserves the phase space volume. At the same it gives rise to the conservation of entropy or information under Hamiltonian dynamics. Now, what is the difference between this and quantum mechanics storing quantum information? For either a pure state is specified by a wave function or a mixed state specified by a density matrix, while Its quantum information content is measured by von Neumann entropy similar to, but structurally equivalent to Shannon entropy. In contrast to classical information, we know that quantum information can neither be cloned nor deleted. In quantum field theory, the information is contained in the state again, a linear functional over an operator algebra. The combination of quantum field theory, general relativity and thermodynamics for a black hole uncovers a problem, the so-called paradox of black hole information loss. The information should be usually conserved in a black hole, where no particle/radiation can be emitted. But Hawking radiation contradicts this conservation of information. Hawking asserted that the emitted radiation from a black hole is thermal and its detailed form is independent of the structure of matter that collapsed to form the black hole. But there is the possibility that the Hawking radiation is entangled with the states in the interior of the black hole, which would solve this paradox.

But what about matter (or the It)? According to the standard model of elementary particle physics, there are quarks and leptons having a rest mass and occupying a non-zero volume (by the Pauli exclusion principle). Furthermore, there

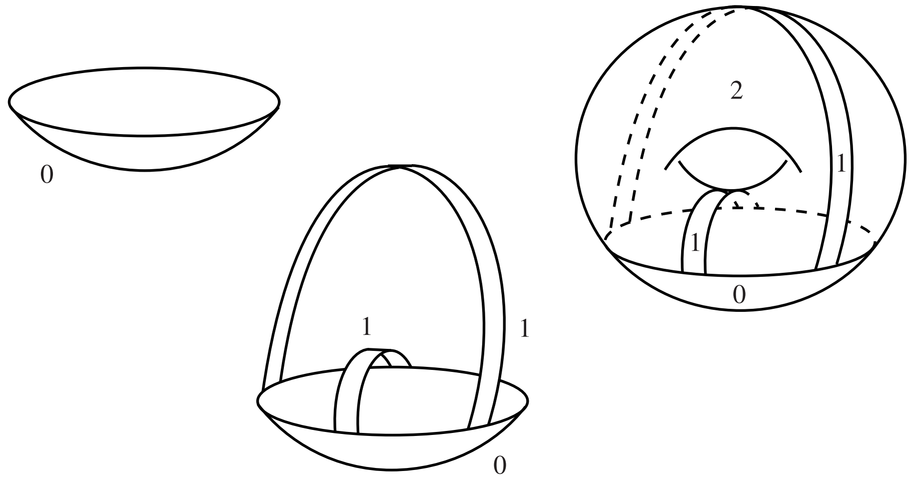

Figure 1: handle decomposition of the torus

are bosons (gluons, W/Z-bosons, photon) mediating the forces between the quarks and leptons. All these constituents can appear in different states. A change of a state is directly caused by an interaction. Above we suggested that the state is the direct expression of information. So, it seems that the It implies the Bit. But conversely, the behavior of the It is controlled by the Bit (caused by interactions). In particular, every outcome of an experiment is a stream of bits and also every dynamics can be seen in this manner. I think Wheeler and Weizsäcker had this picture in mind. But Weizsäcker went further when he introduced time as the steering element in the information stream by using its time-like logic. The discussion of the whole complex behind the slogan 'It from Bit' requires the answer to other questions like what is time? or Is the world digital or continuous? (posted by FQXi in the previous contests).

II. THE INFORMATIONAL CONTENT OF THE SPACETIME

When Einstein developed general relativity (GR), his opinion about the importance of general covariance changed over the years. In 1914, he wrote a joint paper with Grossmann. There, he rejected general covariance by the now famous hole argument. But after a painful year, he again considered general covariance now with the insight that there is no meaning in referring to "the spacetime point A" or "the event A", without further specifications. Therefore the measurement of a point without a detailed specification of the whole measurement process is meaningless in GR. The reason is simply the diffeomorphism-invariance of GR which has tremendous consequences. Physical observables have to be diffeomorphism-invariant expressions.

The basic object in GR is a smooth 4-manifold M, the spacetime. The (smooth) atlas of M is called the smoothness structure unique up to diffeomorphisms. One would expect that there is only one smooth atlas for any given topological M, all other possibilities can be transformed into each other by a diffeomorphism. But this is not true, see my previous FQXi essay [3]. In fact, there are infinitely many non-equivalent smoothness structures on certain topological M's with no heuristic to distinguish one above the others as physically relevant. But more importantly, the breakup of the concept 'spacetime point' by using the diffeomorphism invariance is much more important. From the informational point of view, it is the reduction of the continuous information contained in a smooth manifold into a discrete set of relevant subsets. More carefully explained, we divide a smooth manifold into a finite set of simple submanifolds. In topology one calls these submanifolds handles and the division of the manifold its handle decomposition. A $k-$handle of a $n-$manifold is the cross product $D^k \times D^{n-k}$ of two disks with $D^k = \left\{ x \in \mathbb{R}^k | \, ||x||^2 \leq 1 \right\}$ having the boundary $\partial D^k = S^{k-1}$ of the $(k-1)-$sphere. Then this $k-$handle will be glued along $\partial D^k \times D^{n-k}$ to the boundary of a $n-$disk, i.e. to the $(n-1)-$sphere. To illustrate the power of this concept, I will give an example, the torus $T^2 = S^1 \times S^1$. We start with a $0-$handle $D^0 \times D^2$, the disk D^2, and add two $1-$handles $D^1 \times D^1$ to the boundary of the $0-$handle (see Fig. 1). Then we close the manifold by a 2-handle $D^2 \times D^0$ and obtain the torus. In this example we have no freedom in the choice of attaching map for the handle. But adding a 2-handle $D^2 \times D^2$ to build a 4-manifold requires an attaching map $\partial D^2 \times D^2 \to \partial D^4 = S^3$ which can be reduced to $S^1 \to S^3$ (by fixing the second disk D^2). But this map is the definition of a knot! So let us summarize:
A smooth manifold can be decomposed into a diffeomorphism-invariant manner by (at most) countably many handles. Then the handles can be simply triangulated by using simplices to end up with a piecewise-linear (or PL) structure.

The surprising result of Cerf for manifolds of dimension smaller than 7 was simple: PL-structure (or triangulations) and smoothness structure are the same. This implies that every PL-structure can be smoothed to a smoothness structure and vice versa. Therefore *the discrete approach (via triangulations) and the smooth approach to defining a manifold are the same*! So, our spacetime admits a kind of duality: it contains discrete information in its handle structure but it is a continuous space at the same time. Both approaches are interchangeable.

But an important question remains: Is it possible to obtain this discrete information? Unfortunately, the answer is NO! To understand the core of this answer, I have to introduce an important topological invariant: the fundamental group. Consider all closed curves in a manifold. Two curves are equivalent if the two curves can be continuously deformed into each other (by a so-called homotopy). The equivalence classes of these closed curves forms a group under concatenation, the fundamental group. Beginning with dimension 4, every finitely generated, discrete group can be the fundamental group of a manifold. But then we have the word problem, i.e. for two given fundamental groups we cannot decide whether these groups are isomorphic or not [4]. There is no algorithm for a decision! Or, for two measurements of the fundamental group of the spacetime, we cannot decide whether the two measurements are equivalent. But then we obtain a contradiction to our understanding of an experiment: An replication of the same experiment produces a result but we cannot decide whether it is identical to a previous result.
For two data sets of the spacetime, there is no algorithm to compare the two sets. The result of an experiment is undecidable.
But what is the spacetime in Wheeler's concept? If we do an experiment to measure an observable then we have to choose a coordinate system (a chart in the 4-manifold). Take for example the Stern-Gerlach experiment to measure the spin of an electron. The inhomogeneous magnetic field breaks the isotropy of the space and defines a coordinate system. Then we obtain two streams, electrons with spin $+\frac{1}{2}$ and with spin $-\frac{1}{2}$ which are space-like separated from each other. Therefore the knowledge of a measurement requires a coordinate system. But spacetime is more. It is the possible set of spacetime points therefore containing all information about coordinates and by the argumentation above in principle also all measurement results. In this spirit, I will state:
The spacetime is the Bit.

III. FROM SPACETIME TO MATTER: FROM BIT TO IT

In the previous section we discussed the informational content of the spacetime, the Bit. Now I will bridge the gap to the It, the matter. My plan is the derivation of matter from the space or better the geometrization of matter. Unfortunately, this section is the most technical part of the essay. The reader not willing to follow the argumentation can switch to the next section but keeping in mind: *matter and interaction (as gauge theories) can be described as special submanifolds of the space where these submanifolds are determined by the smoothness structure of the spacetime.*

Differential topology is the mathematical theory of smooth manifolds including the (smooth) relations between submanifolds. Let us consider the effect of the change of the smoothness structure (to a non-equivalent one). As an example of this change I consider a compact 4-manifold M (topologically complicated enough, i.e. a K3 surface or more) containing a special torus T^2_c (so called c-embedded torus). Now cut out a neighborhood $D^2\times T^2_c$ of this torus (with boundary a 3-torus T^3) and glue in $(S^3\setminus(D^2\times K))\times S^1$ (having also the boundary T^3) where $S^3\setminus(D^2\times K)$ denotes the complement of a knot K in the 3-sphere S^3. Then one obtains

$$M_K=\left(M\setminus\left(D^2\times T^2_c\right)\right)\cup_{T^3}\left((S^3\setminus(D^2\times K))\times S^1\right) \quad (1)$$

a new 4-manifold M_K which is homeomorphic to M (Fintushel-Stern knot surgery [5]). If the knot is non-trivial then M_K is not diffeomorphic to M. One calls M_K an exotic 4-manifold, a misleading term. Nothing is really exotic here because all smoothness structures except one (the standard structure) on a 4-manifold are exotic.

What did I change from M to M_K? I simply exchange the torus neighborhood $D^2\times T^2_c$ by a knot complement $(S^3\setminus(D^2\times K))\times S^1$. Therefore, if I want to understand the smoothness change I have to analyze this knot complement and its effect on the 4-manifold. In [6], we have done this job by starting with the Einstein-Hilbert action at M. Then the change from M to M_K produces some new terms which can be interpreted by using the correspondence between embedded surfaces and spinors. An embedding of a surface in $\mathbb{R}^3$ (up to conformal transformations) is determined by a spinor on this surfaces which fulfills the Dirac equation

$$D\phi=H\phi \quad (2)$$

with the 2-dimensional Dirac operator D and the mean curvature H of the embedded surface. The equation (2) looks like an eigenvalue equation to determine the mean curvature. Indeed, one obtains a spectrum of possible geometries for the eigenvalues and any other geometry (or embedding) is a linear combination of eigen vectors. Here, the curvature is quantized without using a quantization of the space (or the spacetime). I do not want to go into the full details but

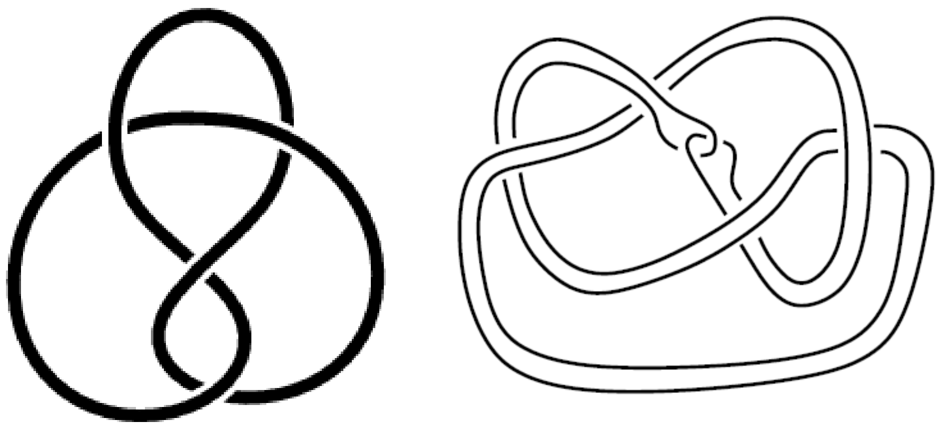

Figure 2: satellite knot: figure-8 knot (left) and the Whitehead double of it (right)

with the help of this theory we were able to derive the Dirac action from the Einstein-Hilbert action. Then the spinor can be directly interpreted as knot complement of the thicken knot $D^2 \times K$ above. But we went a step further and analyze more complex knots, so-called satellite knots (see Fig. 2) Then we obtain a pair of spinors (represented by the two knot complements) which are connected by a torus bundle. A torus bundle can be obtained by taking two copies of $T^2 \times [0,1]$ and gluing them together. The complexity of this torus bundle depends on the gluing map $T^2 \to T^2$. But there are only three possible gluing maps, so one obtains only three different torus bundles. It was a surprise for us to obtain also the Yang-Mills action in this approach. Then the three types of torus bundles are directly related to the photon, W/Z-bosons and gluons where we automatically obtain the mixing between photon and Z-boson. These results are promising but which knot corresponds to an electron etc.? Here we have only a rough idea to determine the class of knots. A complement of a knot $S^3 \setminus (D^2 \times K)$ is a complex 3-manifold with torus boundary T^2 which can be represented by branched coverings of the 3-sphere. Here I will only make the remark that every 3-manifold can be represented by a 3-fold branched covering of the 3-sphere branched along a knot (a deep theorem of Hilden and Montesinos). Using this result, we are able to determine the knots. At first, the branching set for a knot complement is not a (closed) knot but rather a braid (or knotting strands which are not closed to form a knot). Then, a 3-fold covering induces 3-strand braids as branching set. The braid starts and ends at the boundary so that the interaction can be described by concatenation of braids. This ansatz has many parallels to the Bilson-Thompson model [7] and its extension by Smolin et.al. [8].

IV. TIME AS REGULATORY ELEMENT: FOLIATING THE BIT TO PRODUCE SEQUENCES

In the previous section I unified the Bit and the It in some sense. I derived the It from the Bit but the reverse way is also possible. Now, matter and space have the same root. But I ignored one important element: the order in the Bits. Usually we have sequences of data as the outcome of an experiment. The sequence is an expression of the dynamics and for a given position in the sequence we know the unique precursor and successor. This order structure is denoted as *Time*. But at least with the advent of quantum mechanics we know about the problem of the open future. The outcome of an experiment cannot be known for sure in general. If our spacetime model using exotic smoothness is successful then it should be possible to explain this situation.

The choice of space and time in a spacetime is the determination of a foliation (of codimension one). I remark that Shape dynamics [9, 10] uses also foliations defined in a local way. Standard arguments in GR like causality and Lorentz invariance enforces the choice (up to diffeomorphisms) $\Sigma \times \mathbb{R}$ (see [11, 12]) with a 3-manifold Σ as space. It is also a codimension-one foliation but a global one, i.e. $\Sigma \times \{t\}$ with $t \in \mathbb{R}$ are the (spatial) leafs. An exotic version of $\Sigma \times \mathbb{R}$, denoted by $\Sigma \times_\theta \mathbb{R}$, cannot be (smoothly) foliated in a global manner, see the Fig. 3 for an example (the foliation of teh torus by infinitely extended planes, the so-called Reeb foliation). It would contradict the exotic smoothness structure: Every 3-manifold Σ has a unique smoothness structure which would imply a unique structure for $\Sigma \times \{t\}$ and therefore for the whole $\Sigma \times \mathbb{R}$. Thus we have to choose a different foliation. Importantly the existence of a codimension-one foliation do not depend on the smoothness structure. In the following I consider the special case of a 3-sphere $\Sigma = S^3$. Then there is no foliation along $\mathbb{R}$ but there is a codimension-one foliation of the 3-sphere S^3 (see [13] for the construction). So, $S^3 \times_\theta \mathbb{R}$ is foliated along S^3 and the leafs are $S_i \times [0,1]$ with the surfaces $\{S_i\}_{i \in I} \subset S^3$.

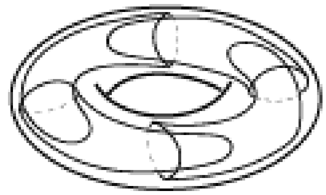

Figure 3: Foliation of the torus (Reeb foliation)

But otherwise we know that $S^3 \times_\theta \mathbb{R}$ is topologically $S^3 \times \mathbb{R}$. What happens if we enforce a foliation to admit a global time, i.e. with the leafs $S^3 \times \{t\}$? Or equivalently, what happens with the 3-spheres in $S^3 \times_\theta \mathbb{R}$? There is no smoothly embedded S^3 in $S^3 \times_\theta \mathbb{R}$ (otherwise it would have the standard smoothness structure). But there is a wildly embedded S^3! Let $i : K \to M$ be an embedding of K (with $\dim K < \dim M$). One calls the embedding i wild if $i(K)$ is not a finite polyhedron (or $i(K)$ is not triangulated by a finite number of simplices). In [14], we considered wildly embedded submanifolds as models of quantum D-branes. The prominent example of a wildly embedded submanifold is Alexanders horned sphere. Wild embedded submanifolds are fractals in a generalized sense . In [15] we argued that this wild embedding is a geometric model for a quantum state. In particular we showed more: the (deformation) quantization of a tame embedding is a wild embedding! If I assume that the spacetime has the right properties for a spacetime picture of quantum gravity then the quantum state must be part of the spacetime or must be geometrically realized in the spacetime. Consider (as in geometrodynamics) a 3-sphere S^3 with metric g. This metric (as state of GR) is modeled on S^3 at every 3-dimensional subspace. If g is a metric of a homogeneous space then one can choose a small coordinate patch. But if g is inhomogeneous then one can use a diffeomorphism to "concentrate" the inhomogeneity in a chart. Now one combines these infinite charts (I consider only metrics up to diffeomorphisms) into a 3-sphere but without destroying the infinite charts by a diffeomorphism. Wild embeddings are the right structure for this idea. A wild embedding cannot be undone by a diffeomorphism of the embedding space. For the example of Alexanders horned sphere we determine the observable algebra in [15]. It is the hyperfinite factor III_1 von Neumann algebra having the structure of the local algebras in a relativistic QFT with one vacuum vector.

In this model we have one lesson learned: the choice of a global time produces a quantum state (the wildly embedded 3-sphere) but the choice of a local time structure gives a complicated partition of the space. The transition between these two possible foliations is strongly related to the measurement process which will be discussed in the next section. Now I will concentrate on the appearance of time. Above I discussed the foliation problem of exotic $S^3 \times_\theta \mathbb{R}$, i.e. in the terminology of GR this kind of spacetime is not globally hyperbolic. In particular it must contain naked singularities. The structure of these singularities is also known: all singularities are saddle points (see Fig. 4 left), i.e. some geodesics meet at the saddle point. This kind of singularity (see Fig. 4 middle) has nothing to do with diverging curvatures or metrics. It has a hyperbolic geometry and a finite curvature. The saddle point violates the strong causality in GR but it is what I want. The strong causality in GR is equivalent to a completely deterministic system (like the block universe of Parmenides). If I believe in an open future then I have to introduce the saddle point: some geodesics going to this point whereas some of the geodesics going away from this point (see Fig. 4 middle). But without a resolution of the saddle point (see Fig. 4 right), I do not know how geodesics pointing to the saddle point are related to the geodesics going away from the saddle point. But exotic smoothness tells us more: the whole weave of saddle points (the Casson handle) in an exotic spacetime forms a tree! So, in contrast to the many-world or branching spacetime interpretation we have another picture: *the spatial component of the spacetime looks like a tree in the time direction called future where the branches of the tree are the possible spatial components.*

V. MEASUREMENT: UNCOVERING THE BIT

In the description of the exotic $S^3 \times_\theta \mathbb{R}$ by foliations, I introduced the wildly embedded 3-sphere as quantum object (seen as quantization of a tame embedded 3-sphere). A measurement of the quantum object (wildly embedded S^3) should result in a classical space (a tame embedding). The construction of $S^3 \times_\theta \mathbb{R}$ is rather complicated (see [16]). As a main ingredient one needs a homology 3-sphere Σ (i.e. a compact, closed 3-manifold with the homology groups of the 3-sphere) which does not bound a contractable 4-manifold (i.e. a 4-manifold which can be contracted to a point by a smooth homotopy). Interestingly, this homology 3-sphere Σ is smoothly embedded in $S^3 \times_\theta \mathbb{R}$ (as cross section,

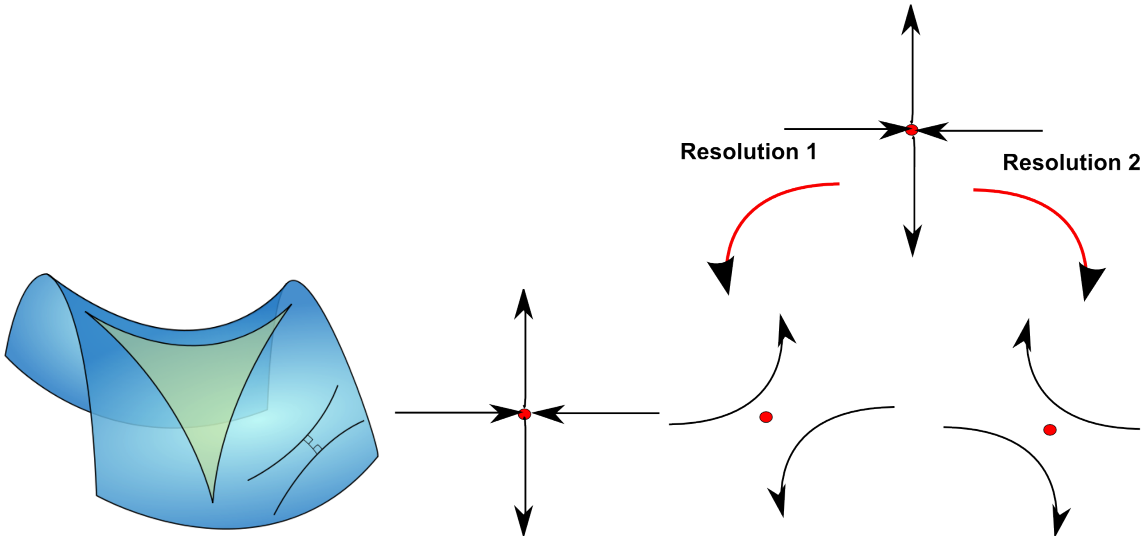

Figure 4: example of a saddle point (left) with the meeting geodesics (middle) and the possible resolutions (right)

i.e. $\Sigma \times \{0\} \subset S^3 \times_\theta \mathbb{R}$). But then we obtain a transition from the wild S^3 (quantum object) to a classical space (tame homology 3-sphere Σ). This transition has much in common with the decoherence process. The wave function encoded in the wild S^3 is reduced to one possible state, the tame Σ[22]. The direction of the transition from the wild S^3 to the tame Σ was dictated by the smoothness structure of $S^3 \times_\theta \mathbb{R}$.

This transition is a global process which can be interpreted as the decoherence process from the quantum space at the Big Bang to a classical space. But for a usual quantum object, we need another theory including a relation between the quantum object and the measurement device. Let us choose a wildly embedded knot complement $\Sigma(K) = S^3 \setminus (D^2 \times K)$ representing a fermion. A possible description of $\Sigma(K)$ is given by a complement of a singular knot (where all crossing of K become double points). Then a resolution of the singular knot gives a concrete knot and we obtain a classical state. Of course the resolution must be a process, i.e. a structure coming from the spacetime. Above I discussed the saddle points. The singularities of the knots are directly related to the singular points of the saddle (see Fig. 4 right)[23]. The procedure to resolve the saddle points was developed by Casson [17] (and further by Freedman): immerse another disk D^2 or better a disk neighborhood $D^2 \times D^2$ to cancel the singular point (or the double point). Equivalently, cancelling the singular point by adding $D^2 \times D^2$ is equivalent to form the sum with $S^2 \times D^2 = S^2 \times [0,1]^2$. At the 3-dimensional level I have to add $S^2 \times [0,1]$ to resolve the singular knot. But what does it mean? In section III, I described the interaction by torus bundles, complicatedly arranged pieces of $T^2 \times [0,1]$. By this procedure I obtained the gauge interactions. Now one would expect that gravitation can be also described by a surface bundle. But except torus bundles, there is only one possible bundle, the sphere bundle $S^2 \times [0,1]$. With these pieces, one can arrange all other possible surface bundles. Now it seems natural to conjecture: *the sphere bundle describes the gravitational interaction.* There are many hints which support this conjecture but no proof. For instance, one can add a sphere bundle to every torus bundle without changing it (universality of gravitation). The gravitational interaction couples to every kind of energy. Therefore one can see gravitation as energy exchange. Let us assume this conjecture then we can *interpret the reason for the reduction of the quantum object (wild knot complement) to the classical state as the gravitational interaction (or the energy exchange) between the measurement device and the quantum object.* This idea is not completely new. Penrose was the first who notice it but without proof. Of course the whole process is only a proposal but it follows directly from our geometric model.

VI. APPLICATIONS: INFLATION AND THE HIGGS

Here I will only shortly describe some of the consequences of the our model. I wrote above that the exotic $S^3 \times_\theta \mathbb{R}$ is characterized by a homology 3-sphere. Now let us assume the exotic $S^3 \times_\theta \mathbb{R}$ as a spacetime model for the cosmos. It starts at $t = -\infty$ with a wildly embedded 3-sphere (which I assume to be of Planck size). Then the model makes a transition to the homology 3-sphere. If we assume a hyperbolic homology 3-sphere then the model shows an exponential increase having all characteristics of inflation [18]. Interestingly the whole model depends only on one parameter, a fraction of two topological invariants of the hyperbolic homology 3-sphere. Here, the reason of the exponential increase during the inflationary phase is given by the tree described in section IV.

A second application of this model was the derivation of the Higgs potential [19]. Here, we analyze the resolution process more carefully. Using a result of Cerf [20], we are able to obtain the Higgs potential together with a one-paramter family of resolutions. The parameter can be interpreted as an expression for the mass of the Higgs boson. It is work in progress but with promising results.

VII. CONCLUSION

I have presented a certain number of ideas and results:

1. Because of diffeomorphism invariance, spacetime seen as smooth 4-manifold contains only a discrete amount of information. Spacetime itself is the Bit.
2. There is a freedom in the definition of the spacetime coming from the choice of the smoothness structure. This idea can be used to identify some submanifolds (related to the smoothness structure) with the matter (fermions and bosons). The It is equal to the Bit.
3. For example consider the foliation of an exotic spacetime like $S^3 \times_\theta \mathbb{R}$ can be very complicated. But the structure of the foliation uncovers the structure of the time. Time is a regulatory element. The past is determined but the future is open.
4. For the usual foliation $S^3 \times \{t\}$ with $t \in \mathbb{R}$ of $S^3 \times_\theta \mathbb{R}$ the 3-sphere must be a wildly embedded submanifold (represented by an infinite polyhedron).
5. A quantum state can be defined on the spacetime as wild embedding. A wild embedding can be seen as a quantization of a tame embedding.
6. This identification between quantum state and wild embedding has a strong impact to understand the measurement process. So, I discussed the possibility that gravitation enforces the state reduction after a measurement.
7. The model of an exotic spacetime has also interesting applications. Inflation can be obtained naturally. Furthermore the form of the Higgs potential can be also determined by arguments using the exotic smoothness.

We will end up this essay with Wheelers words [21] about Time and its meaning: Time, among all concepts in the world of physics, puts up the greatest resistance to being dethroned from ideal continuum to the world of the discrete, of information, of bits. … Of all obstacles to a thoroughly penetrating account of existence, none looms up more dismayingly than 'time.' Explain time? Not without explaining existence. Explain existence? Not without explaining time. To uncover the deep and hidden connection between time and existence … is a task for the future.

Before concluding, I must add that the views expressed are only partly original. I have partially drawn from the ideas of Carl H. Brans, Jerzy Król and Helge Rosé. I was also strongly influenced by the work of C.F. von Weizsäcker.

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